THOMAS

Loss of Hydraulic Head in Small Valves

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LOSS OF HYDRAULIC HEAD IN SMALL VALVES

BY

MOSES EDGAR THOMAS

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

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This is to certify that the following thesis prepared under the direction of Professor A. N. Talbot, Head of the Department of Theoretical and Applied Mechanics, by

MOSES EDGAR THOMAS

entitled LOSS OF HYDRAULIC HEAD IN SMALL VALVES

is hereby approved by me as fulfilling this part of the requirements for the Degree of Bachelor of Science in Civil Engineering.

Ira O. Baker

Head of Department of Civil Engineering

88071

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INTRODUCTION

Very few tests have been made to determine the loss of head through small valves. In view of this fact the writer made a series of tests on small valves and in the following pages has endeavoured to discuss the results and determine formulas which may be useful in calculating the loss of head in pipe systems containing small valves. The losses for sizes other than those tested may readily be obtained by interpolation.

The subject matter is presented in the following:—

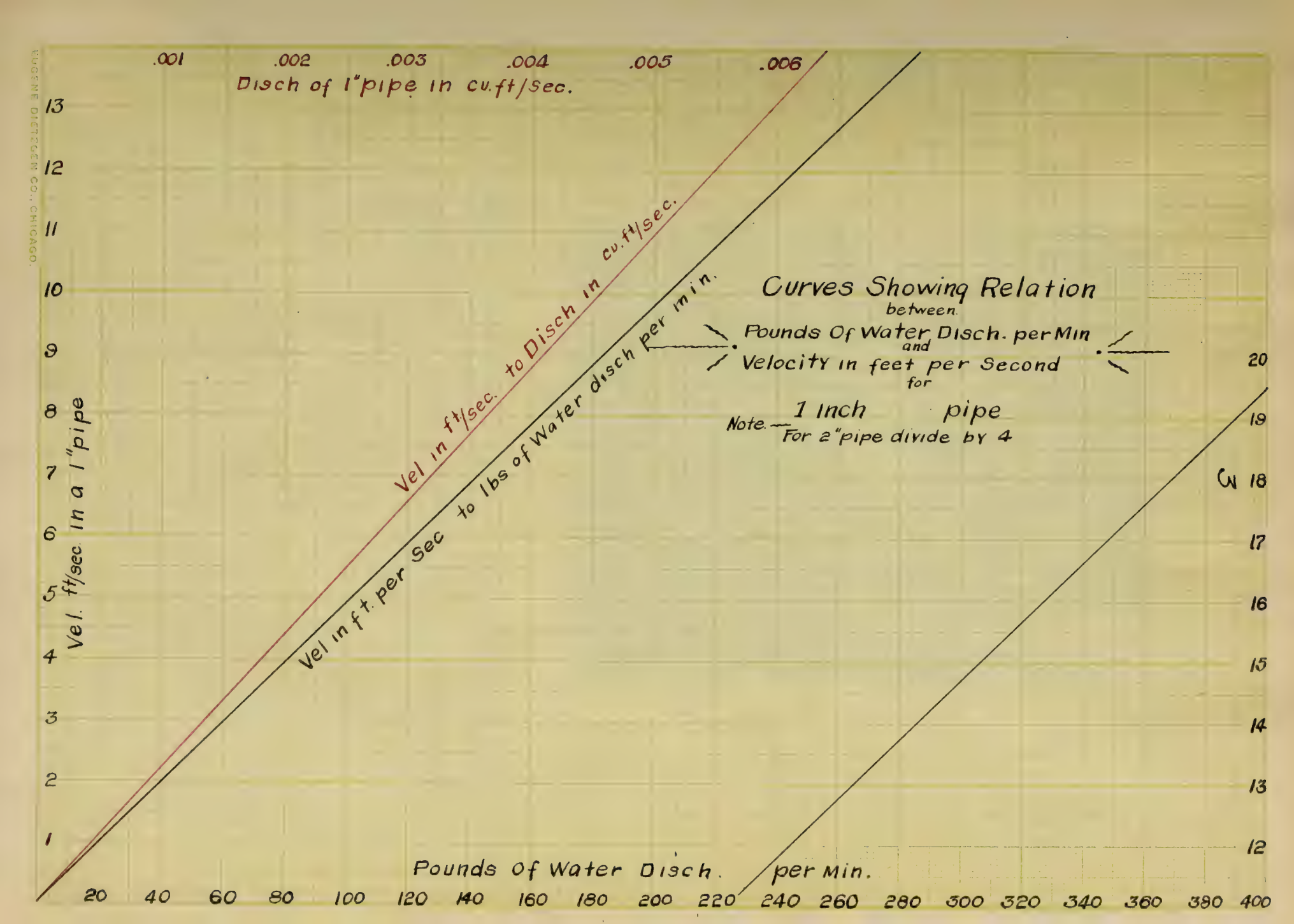
Method of Testing Valves.
Pictures and Sections of Valves Tested.
Curves Showing the Relation of the Velocity in Pipe to Head Lost.
Investigation of the Loss of Head in Gate, Globe, and Angle Valves
Formulas Expressing Head Lost in Terms of the Velocity.
Conclusion.

Method Used in Testing for Loss of Head in Small Valves.

The valves were connected to a stand-pipe so as to be under a constand head of sixty feet. The flow through the valves was regulated by a valve connected beyond those to be tested. Three-way gauge connections were made in the pipe at a distance of one foot on each side of the valve as shown in the pictures pages 4 and 5. Care was taken not to screw the connection into the pipe and thus obstruct the flow. The three-way connections proved to be a doubtful expedient as the pressure in each lead was tested by shutting off the other two and in no case was there an appreciable difference. The friction for the two feet of pipe between the gauge connections and the valve was taken from Weston's Tables. The velocity was determined by weighing the discharge and in a few cases by means of a measuring pit.

The curves on page 3 were used in order to expedite the calculation of the velocities. The

loss of head was measured by a differential mercury gauge, checked by the differences in head as shown by two Crosby Gauges.


.001
.002
.003
.004
.005
.006
Disch of 1" pipe in cu.ft/sec.
Vel in ft/sec. to Disch in cu.ft/sec.
Vel in ft per Sec to lbs of Water disch per min.
Curves Showing Relation
between
Pounds Of Water Disch. per Min
and
Velocity in feet per Second
for
1 Inch pipe
Note. — For 2" pipe divide by 4
Vel. ft/sec. in a 1" pipe
Pounds of Water Disch. per Min.
1
2
3
4
5
6
7
8
9
10
11
12
13
12
13
14
15
16
17
18
19
20
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400

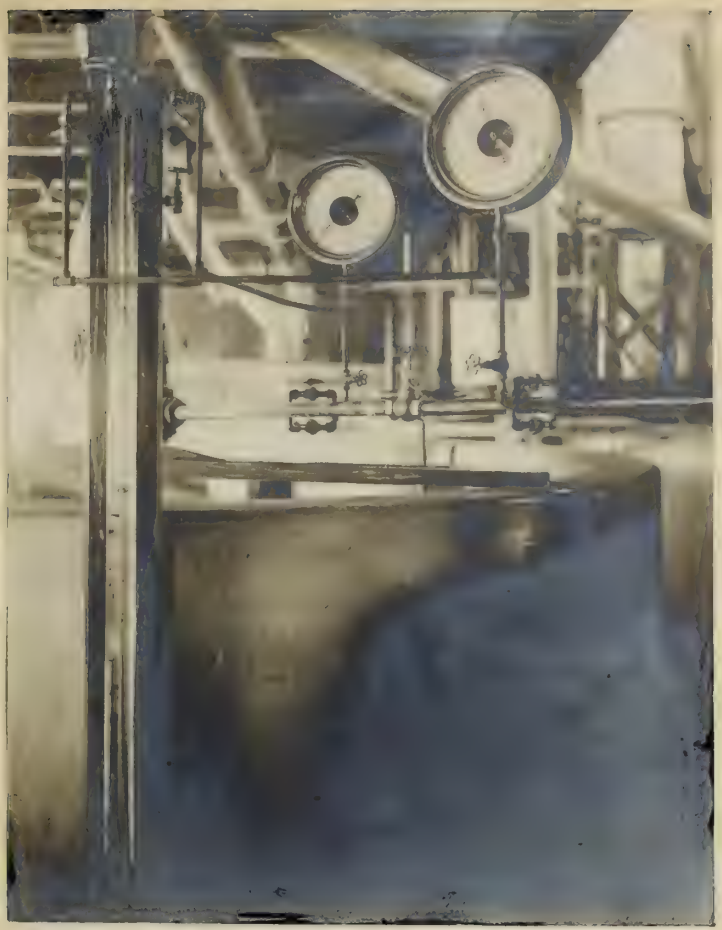


FIG. 1

Picture showing the arrangement of gauges and connections for testing a 1" globe valve.

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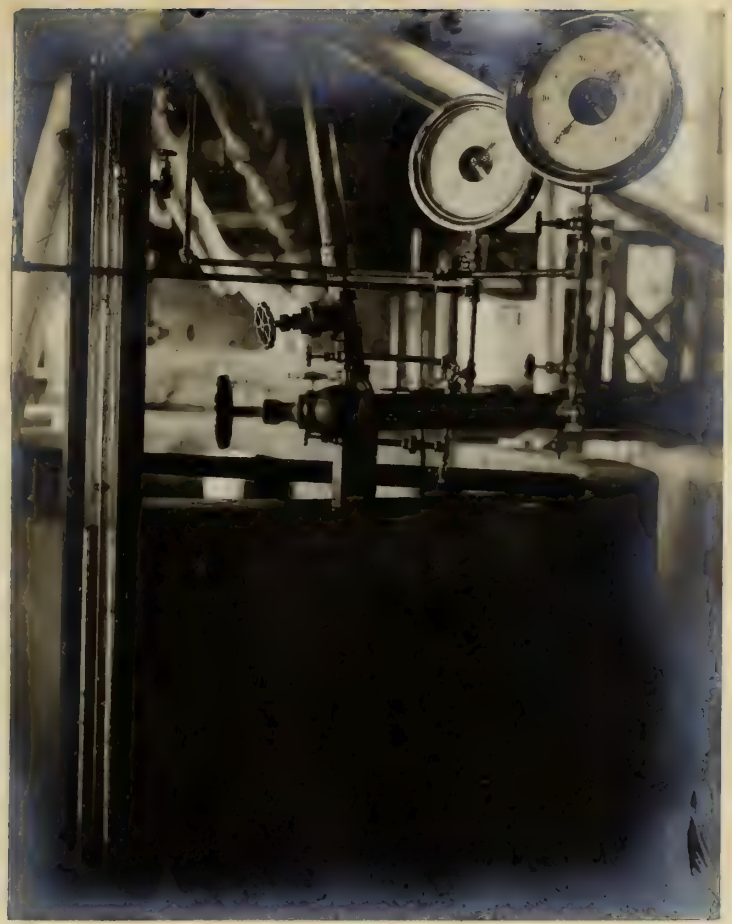

Fig. 2

Picture showing the arrangement of gauges and connections for testing a 2" angle valve.

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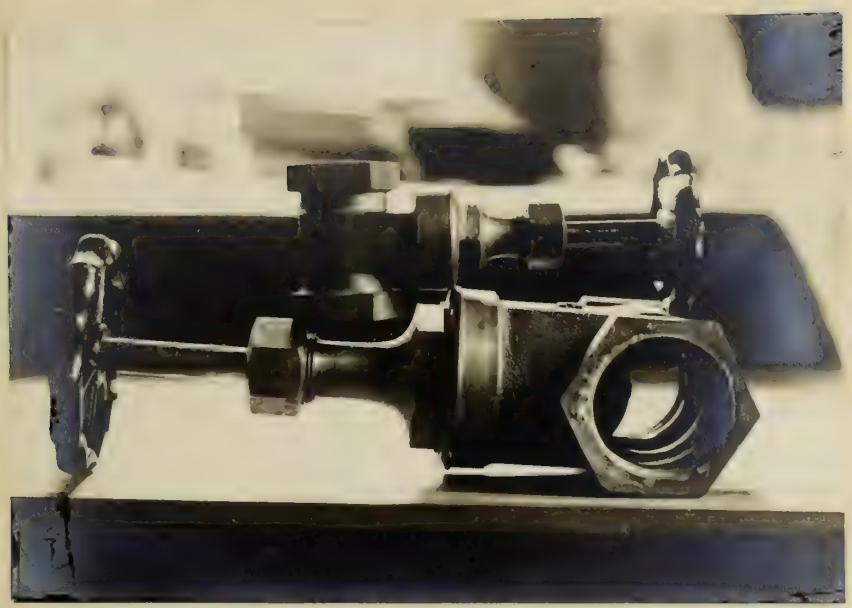

Fig. 3

The gate valves that were tested

Loss of head is shown by curves pages 10 and 11 and by formulas pages 50 to 54.

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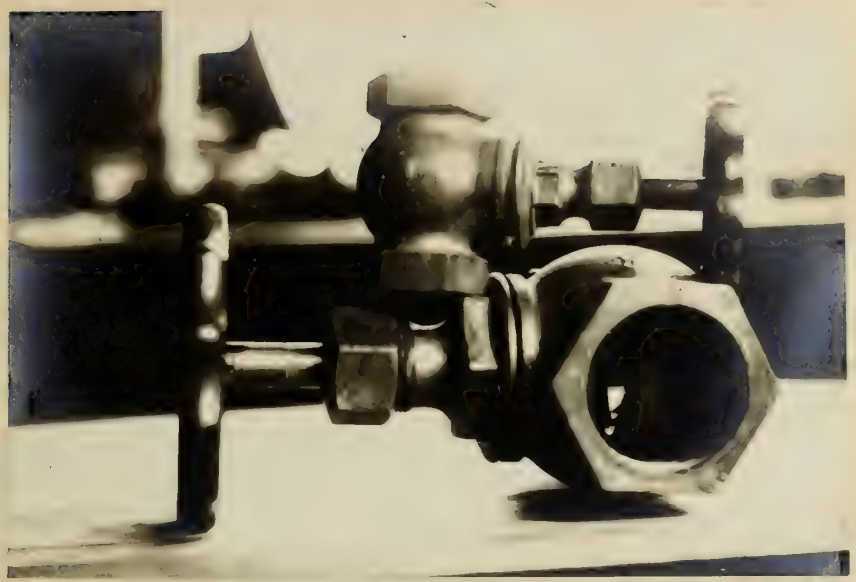


Fig. 4

The Globe Valves That Were Tested.

Loss of head is as shown by curves pages 12 and 13, and by formulas pages 50 to 54.

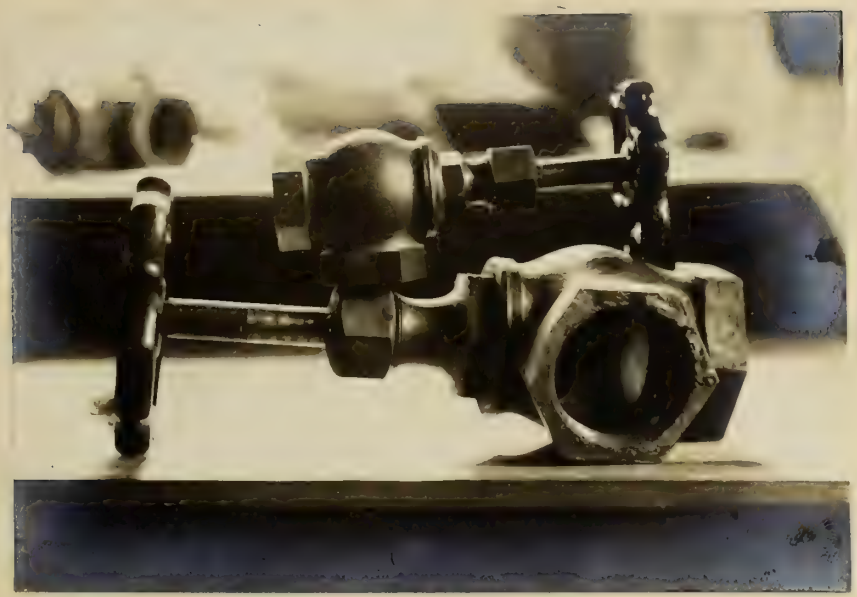


Fig. 5

The Angle Valves That Were Tested

Loss of head is as shown by curves pages 14 and 15, and by formulas pages 50 to 54.

The minimum loss for these valves is when they are about $\frac{2}{3}$ open.

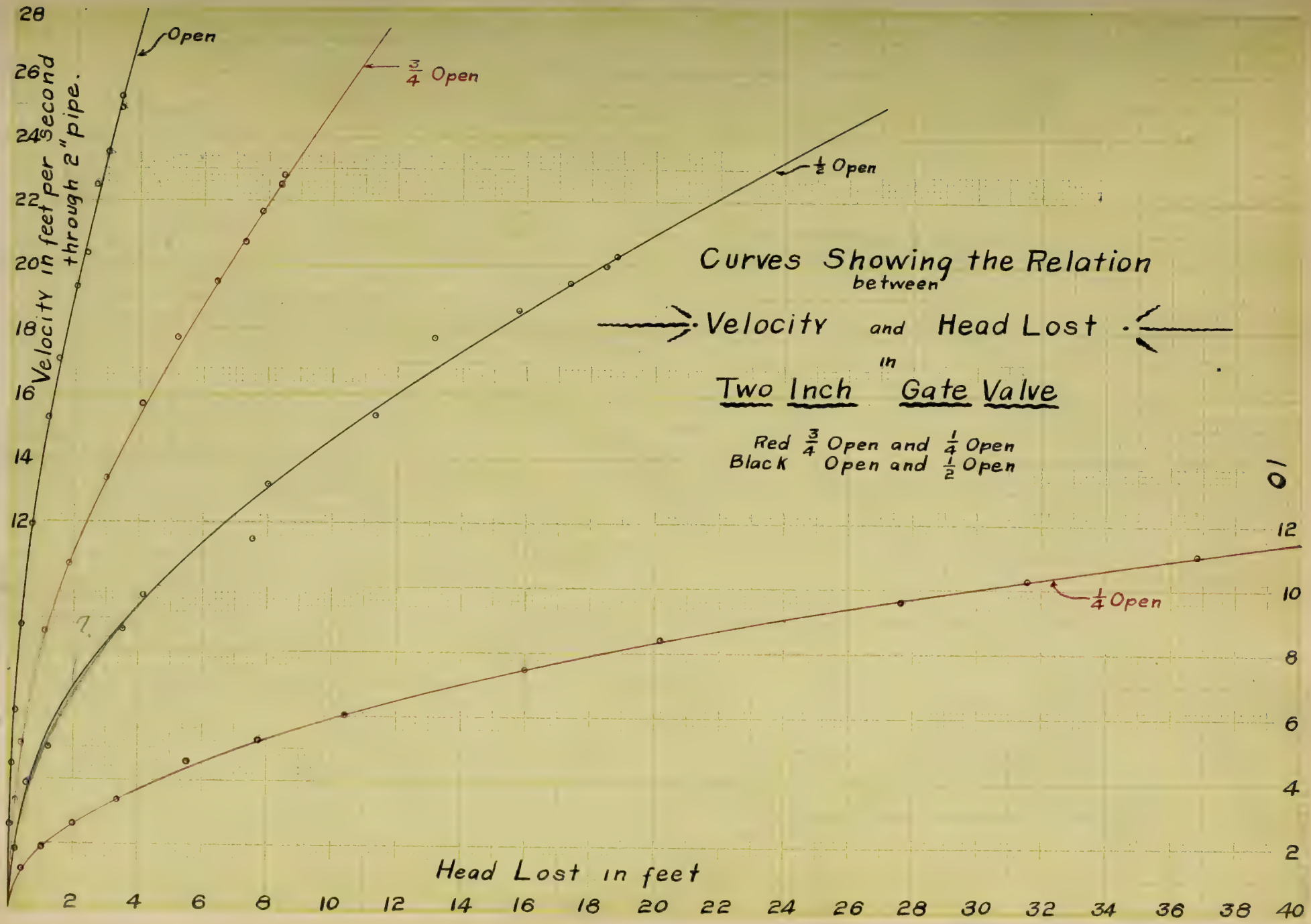
CURVES SHOWING RELATION

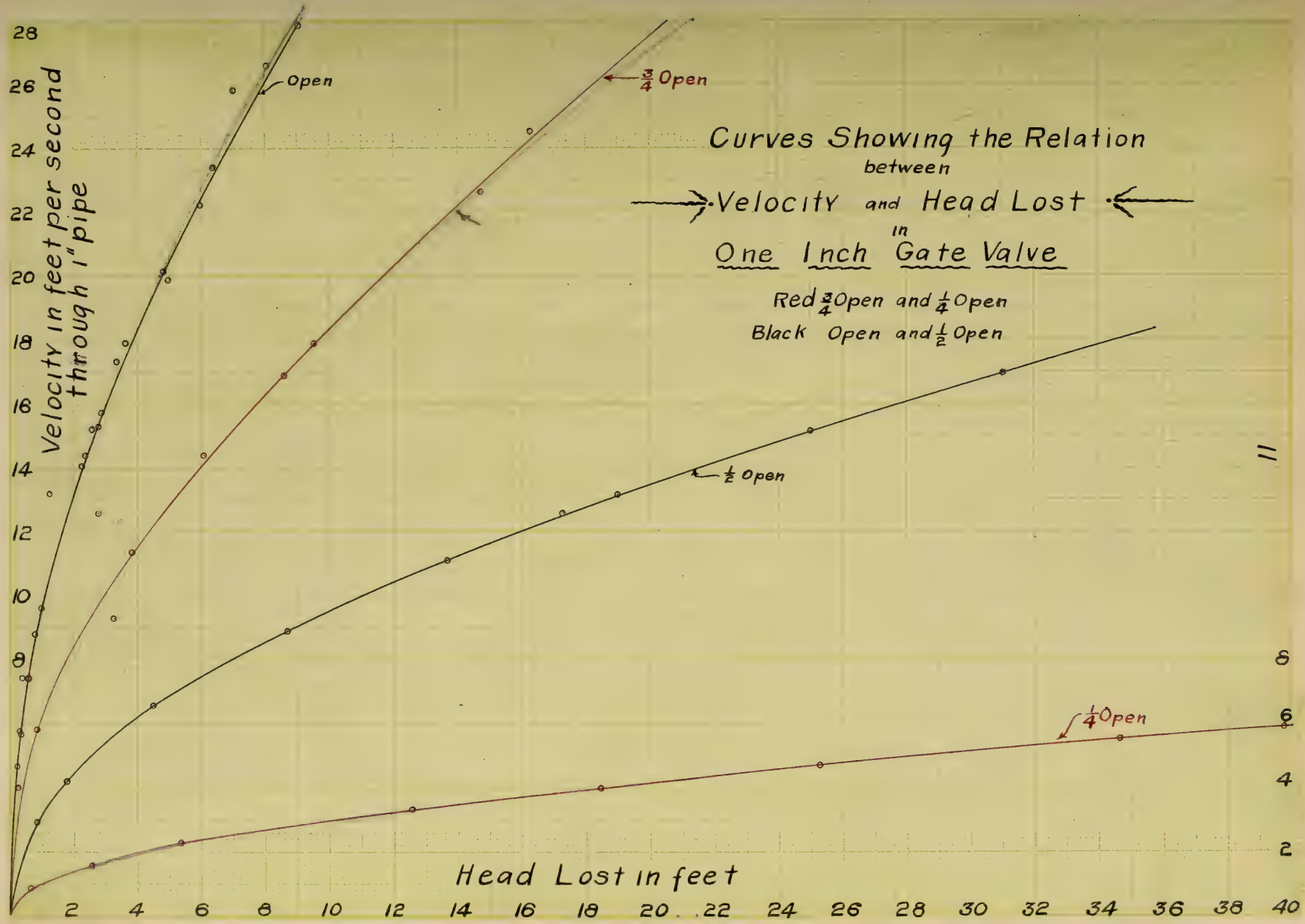
between

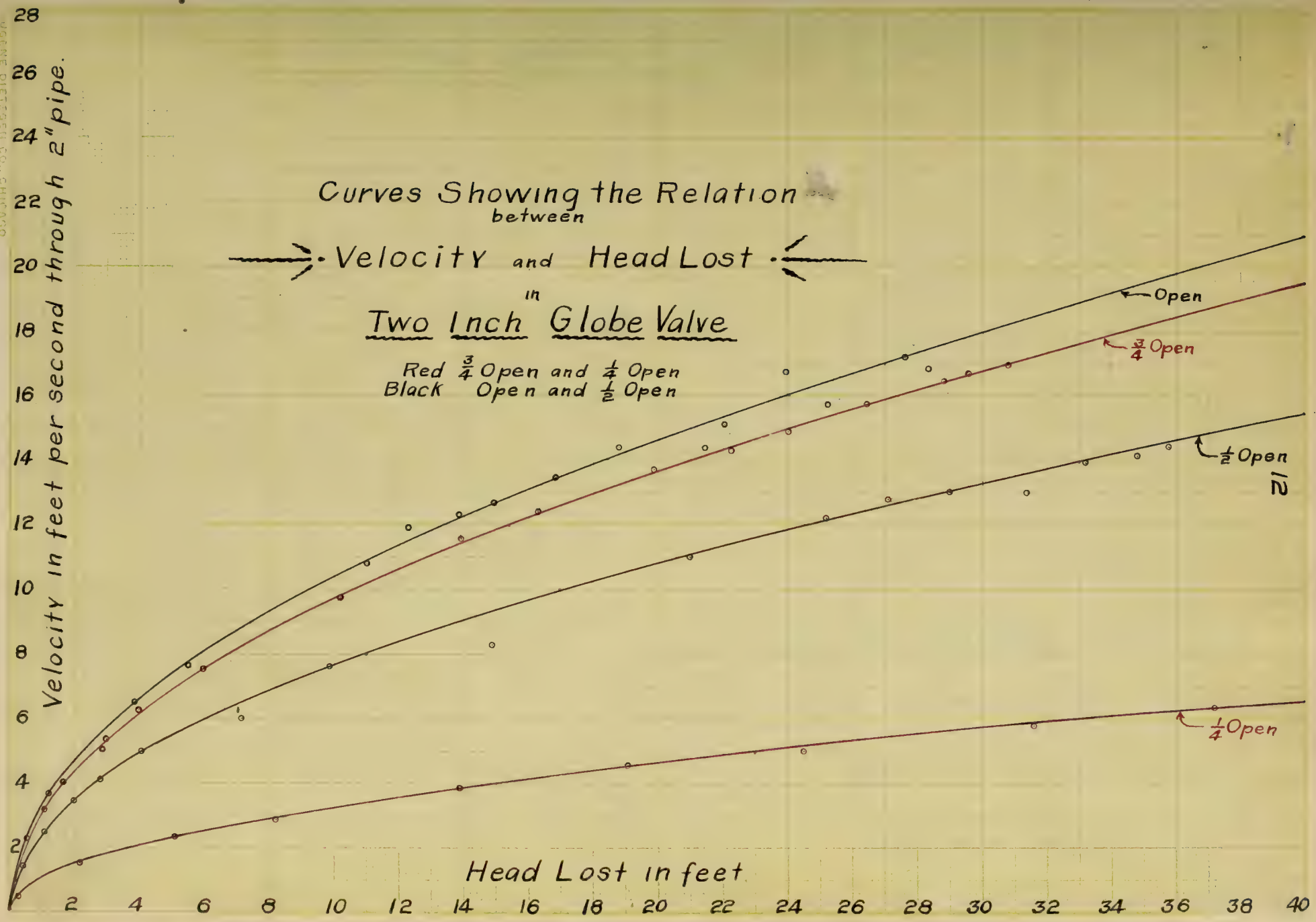
VELOCITY and HEAD LOST

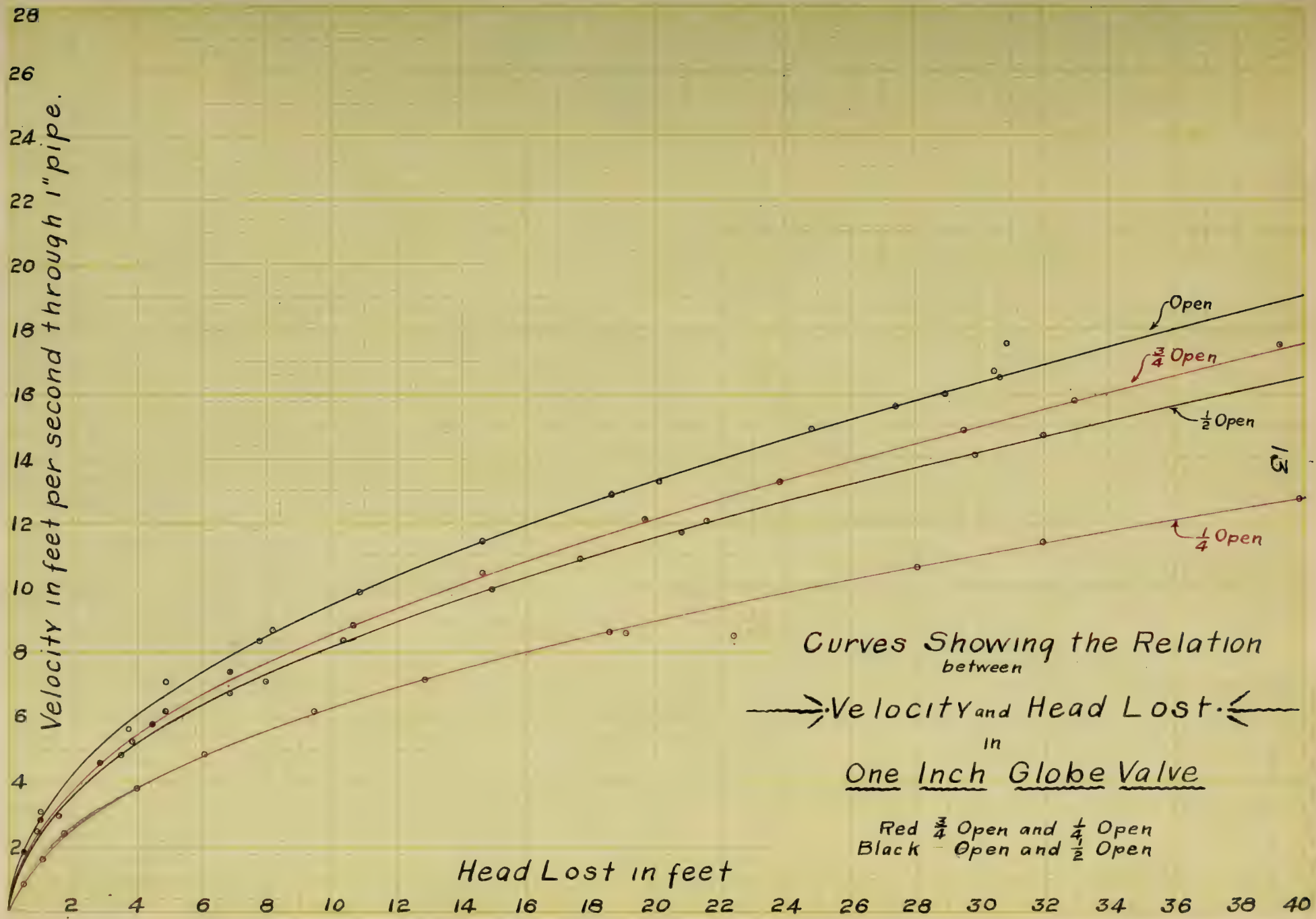
in

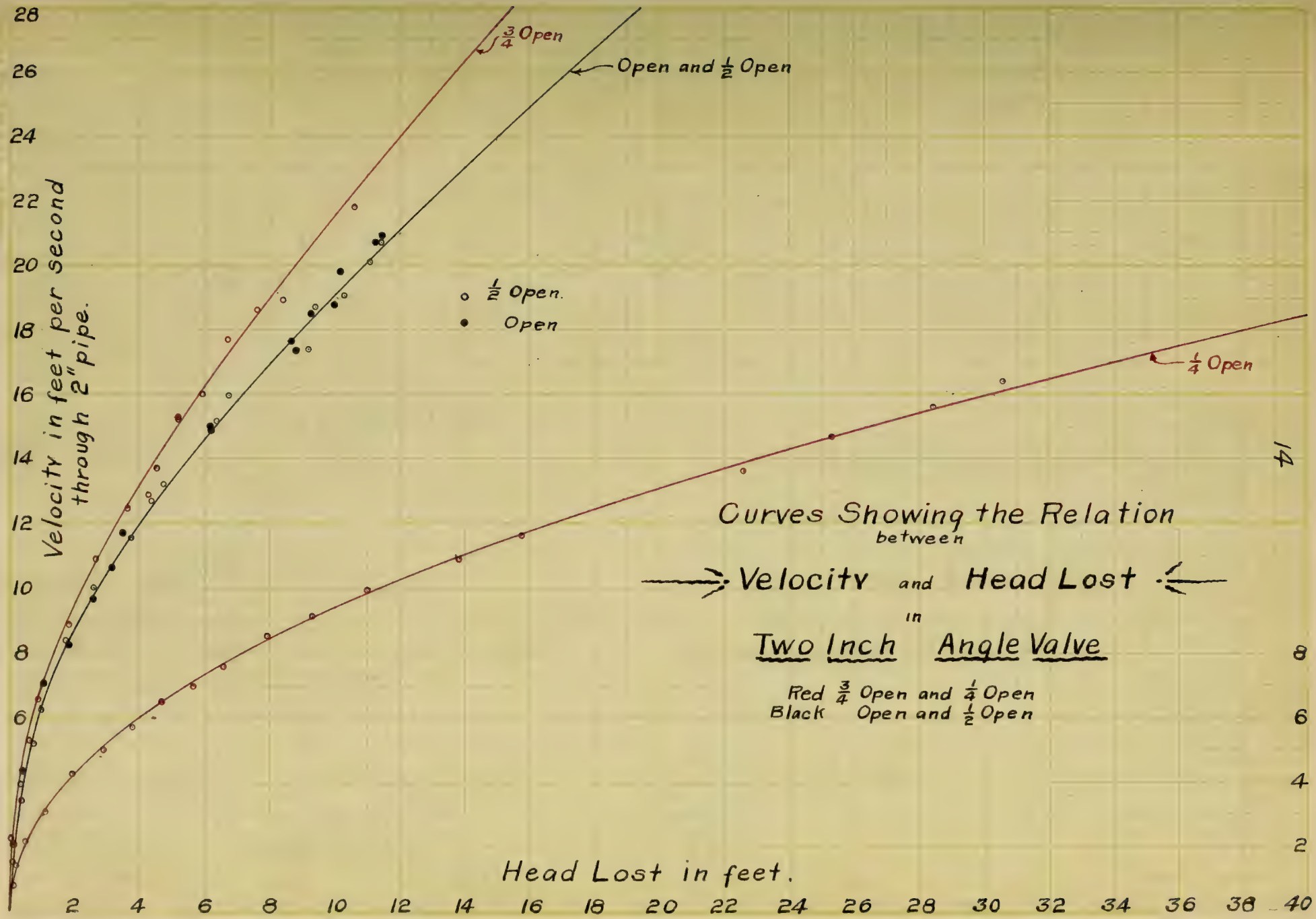
VALVES TESTED

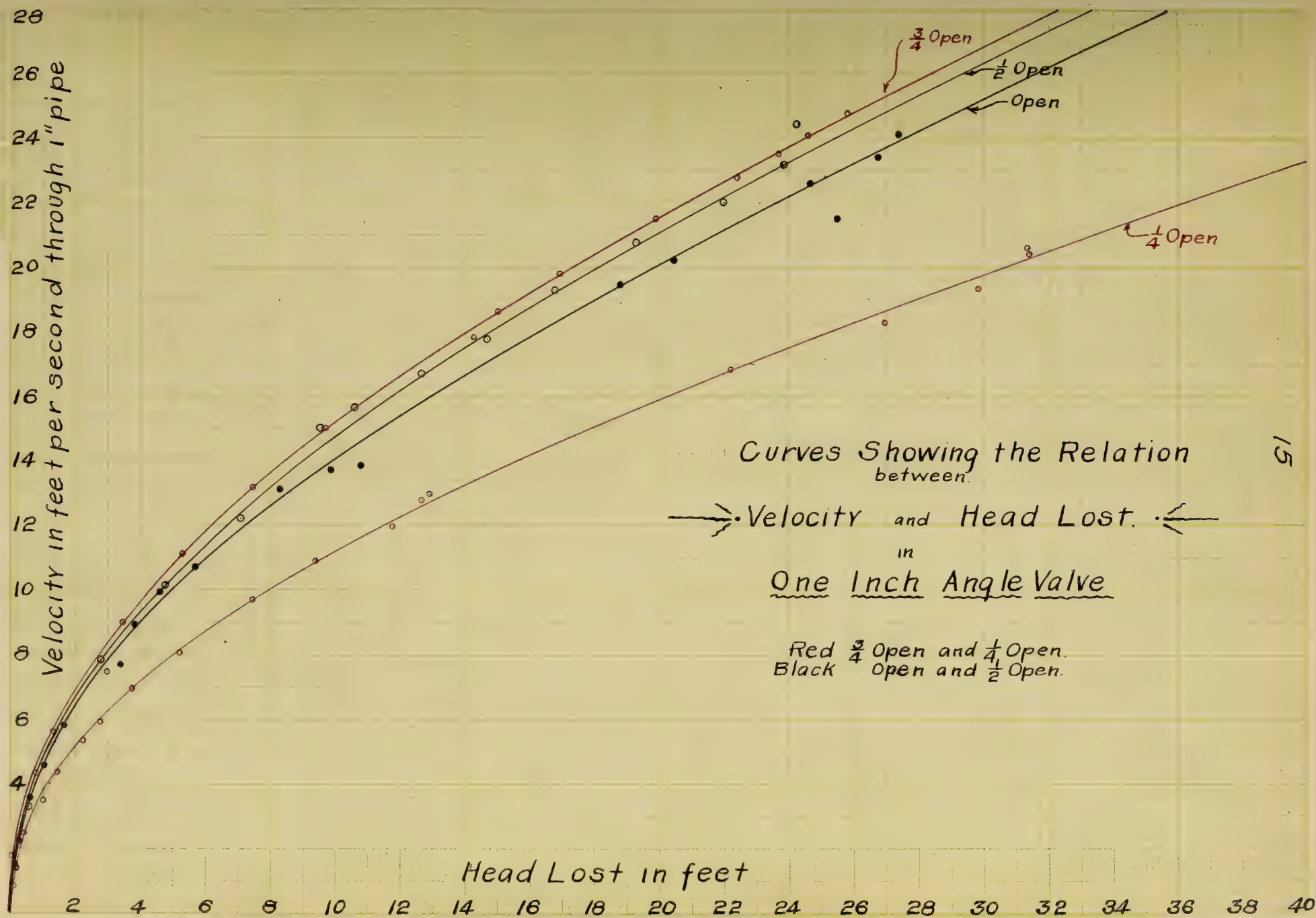

Velocity in feet per second through 2" pipe.
Head Lost in feet
Open
3/4 Open
1/2 Open
1/4 Open
Curves Showing the Relation between Velocity and Head Lost in Two Inch Gate Valve
Red 3/4 Open and 1/4 Open
Black Open and 1/2 Open


Curves Showing the Relation
between
Velocity and Head Lost
in
One Inch Gate Valve
Red ¾ Open and ¼ Open
Black Open and ½ Open
Velocity in feet per second through 1" pipe
Head Lost in feet
Open
¾ Open
½ Open
¼ Open
28
26
24
22
20
18
16
14
12
10
8
6
4
2
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
11
8
6
4
2


Curves Showing the Relation
between
Velocity and Head Lost
in
Two Inch Globe Valve
Red ¾ Open and ¼ Open
Black Open and ½ Open
Velocity in feet per second through 2" pipe.
Head Lost in feet
Open
¾ Open
½ Open
¼ Open
12
28
26
24
22
20
18
16
14
12
10
8
6
4
2
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40


Velocity in feet per second through 1" pipe.
Head Lost in feet
Open
¾ Open
½ Open
¼ Open
Curves Showing the Relation
between
Velocity and Head Lost
in
One Inch Globe Valve
Red ¾ Open and ¼ Open
Black Open and ½ Open


Velocity in feet per second through 2" pipe.
Head Lost in feet.
¾ Open
Open and ½ Open
¼ Open
½ Open.
Open
Curves Showing the Relation
between
Velocity and Head Lost
in
Two Inch Angle Valve
Red ¾ Open and ¼ Open
Black Open and ½ Open


Velocity in feet per second through 1" pipe
28
26
24
22
20
18
16
14
12
10
8
6
4
¾ Open
½ Open
Open
¼ Open
Curves Showing the Relation
between
Velocity and Head Lost.
in
One Inch Angle Valve
Red ¾ Open and ¼ Open.
Black Open and ½ Open.
Head Lost in feet
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

SECTIONS of VALVES TESTED

Drawn to Scale.

Two Inch Gate Valve

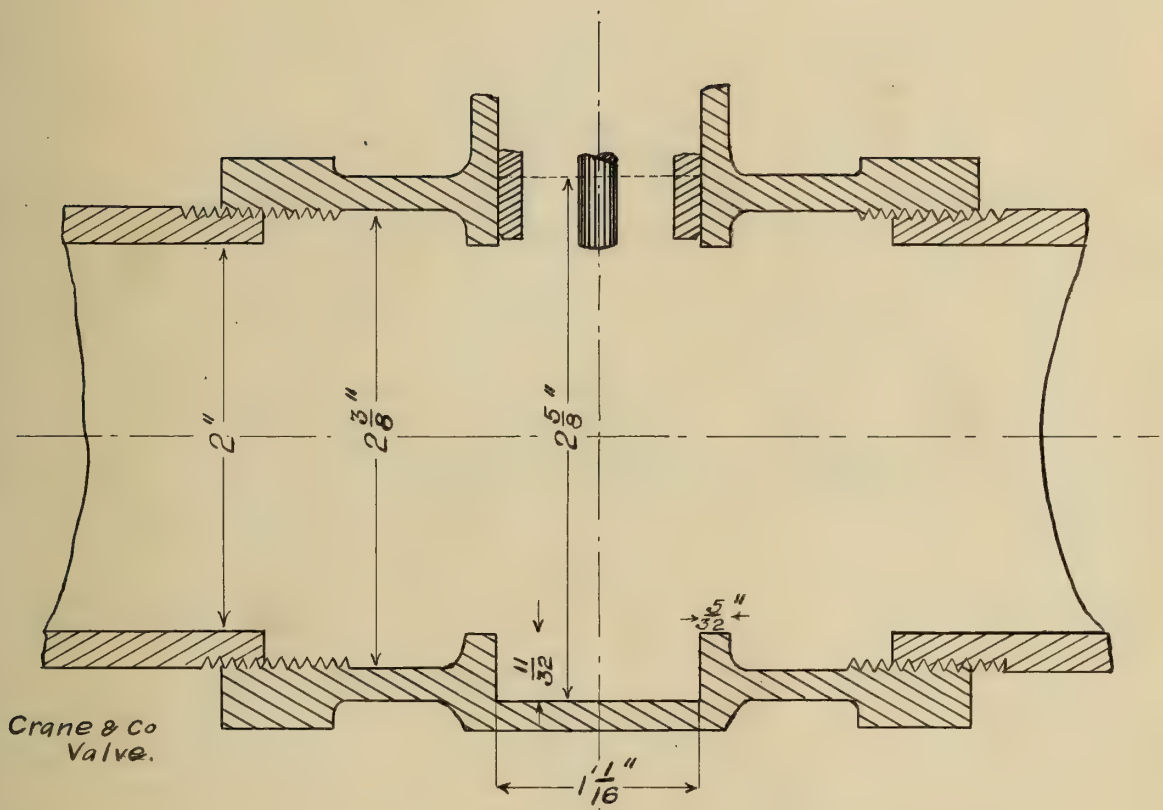


Fig. 6

ONE INCH GATE VALVE

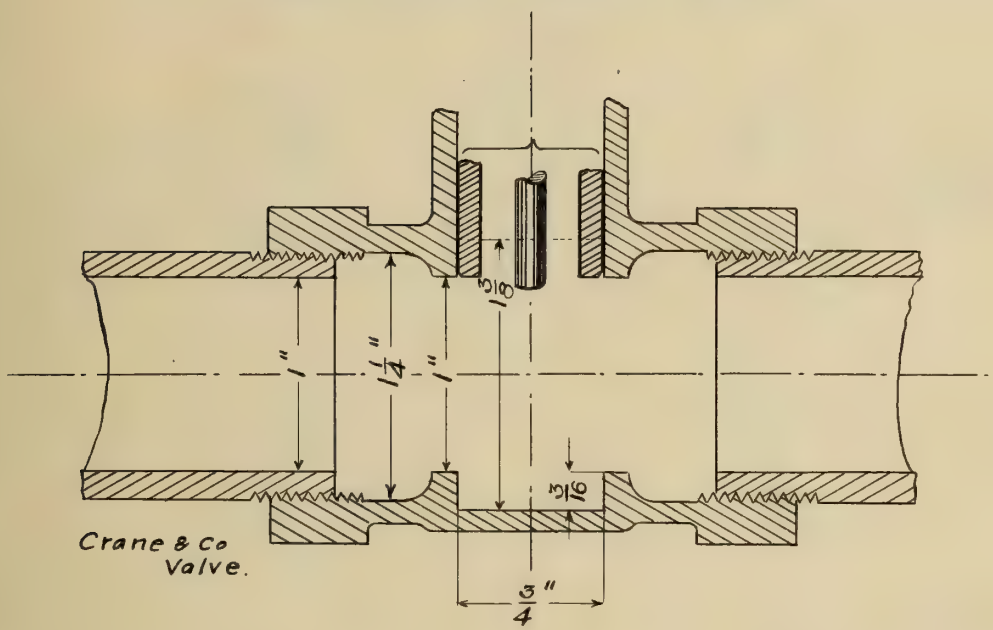


Fig. 7

TWO INCH GLOBE VALVE

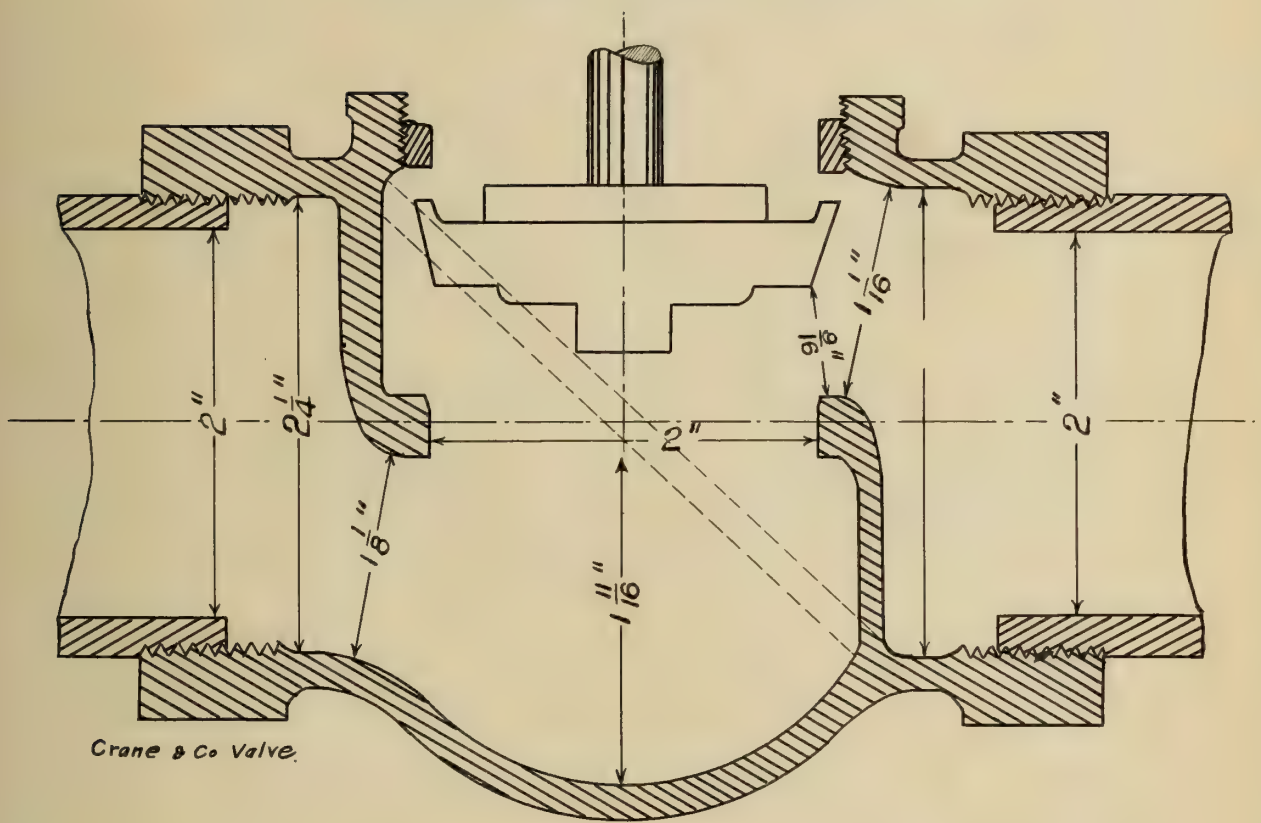


Fig. 8

ONE INCH GLOBE VALVE.

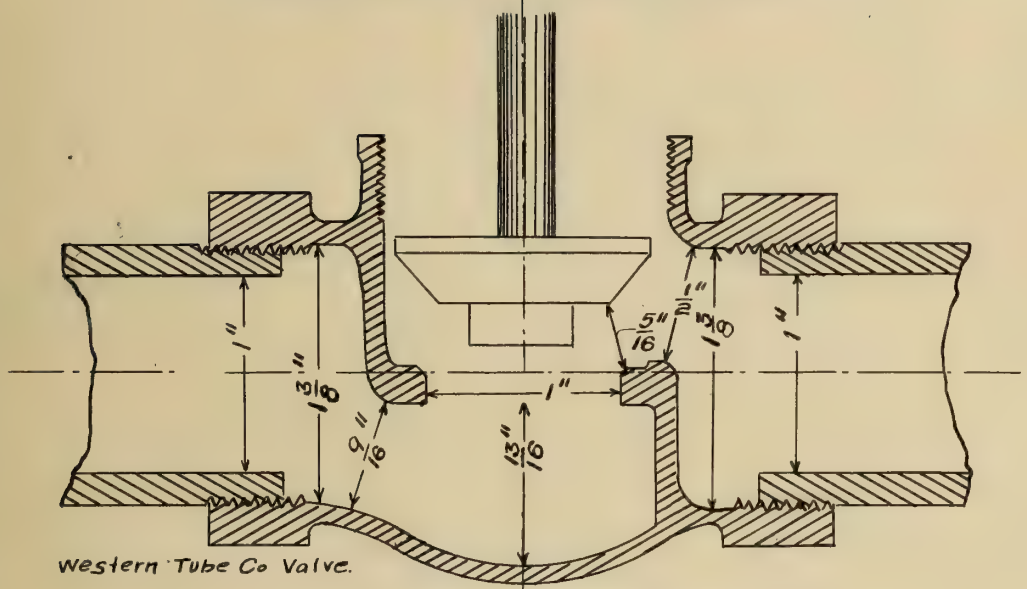


Fig. 9

Two Inch Angle Valve

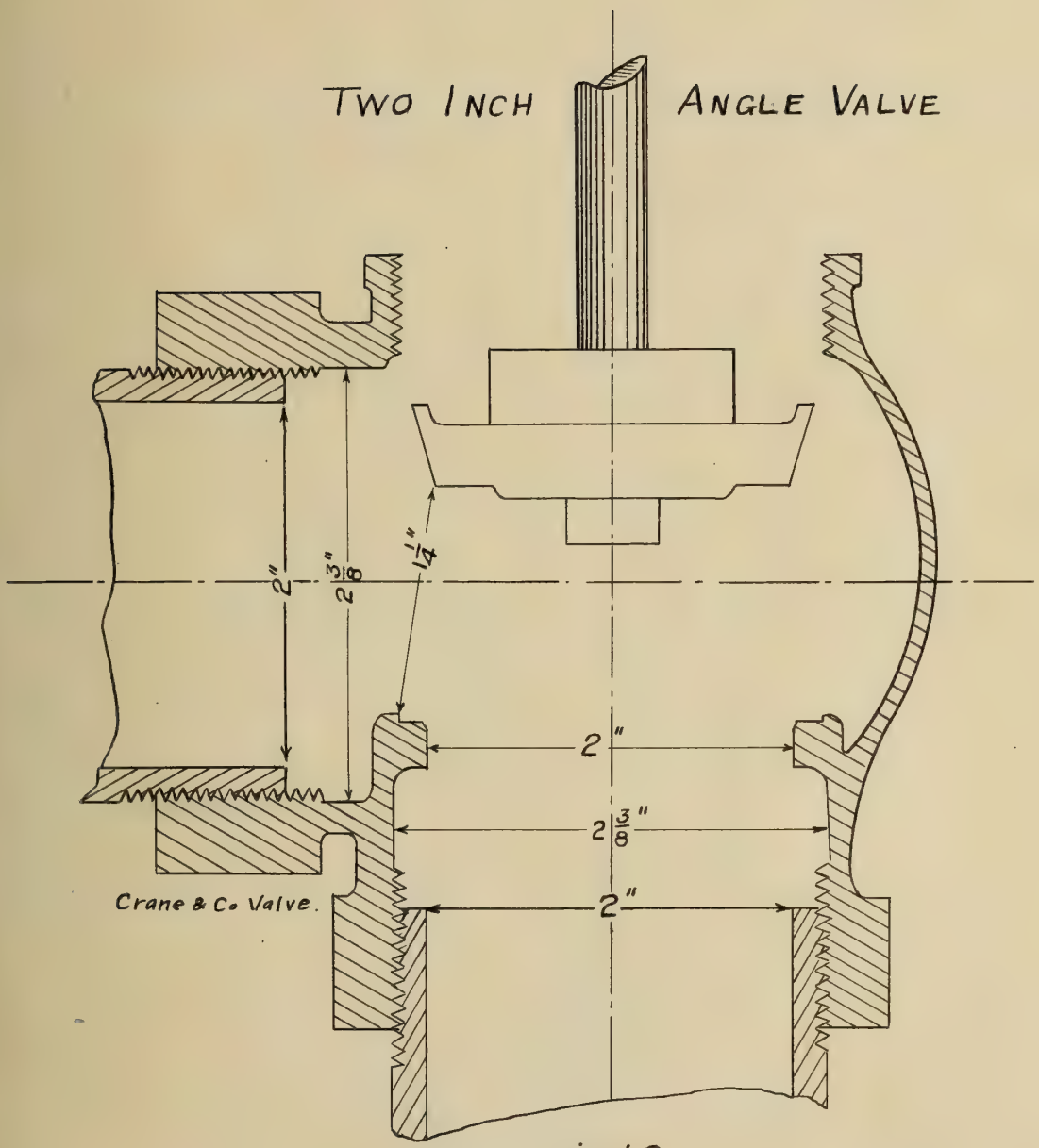


Fig. 10

ONE INCH ANGLE VALVE

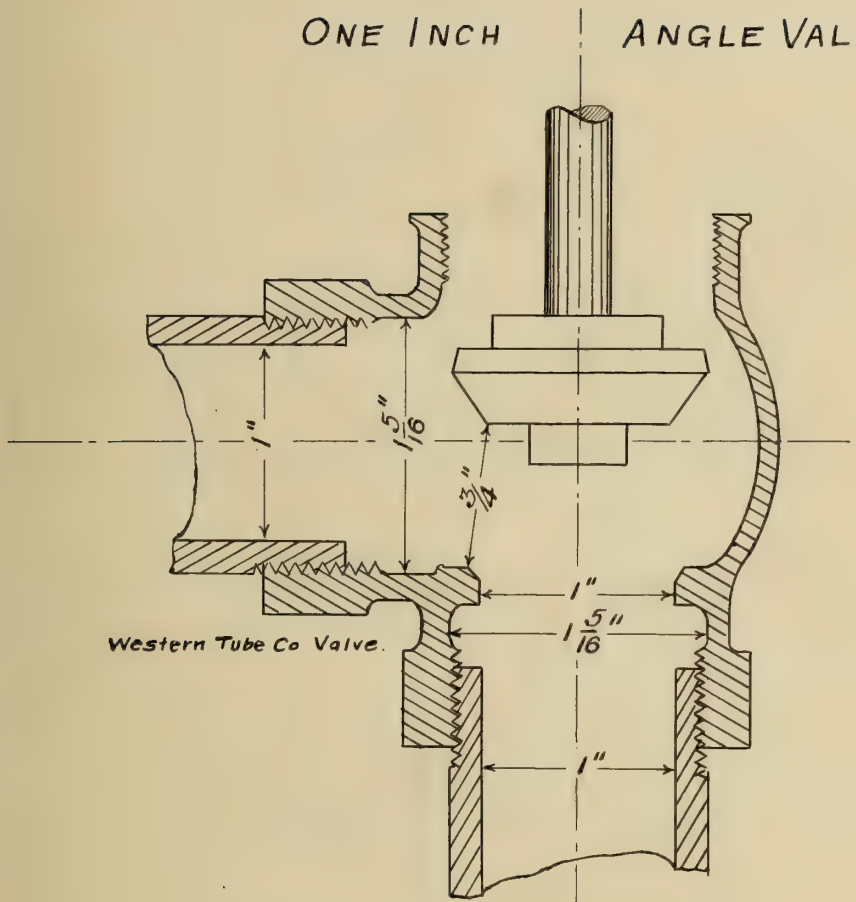


Fig 11

INVESTIGATION
of
LOSS OF HEAD
in
GATE VALVES.

I. 2-in. Gate open, $\frac{1}{2}$ open

II 1-in. Gate open, $\frac{1}{2}$ open

Formulas for Loss of Head.

The losses of head in a valve would in general be of three kinds.

1. Loss of Head Due to Sudden Expansion. (Including Loss Due to Sudden Contraction)
2. Loss of Head Due to Change in Direction
3. Loss of Head Due to Friction.

These losses, to a great extent are all due to impact, which results in swirls and foam thus dissapating the energy which is lost. The loss due to sudden expansion is an impact loss caused by the sudden lessening of the velocity at the expanded section. The friction losses may also be regarded as due to sudden expansion and impact, since the small roughness over which the water passes causes a contraction followed by an expansion of the section.

The loss due to expansion is the only one capable of theoretical treatment for the changes of section can be measured. The loss due to friction has been well determined from experiments conducted,

to determine the same, but the loss due to change of direction is but roughly known.

The formulae here presented are taken from "Merriman's Hydraulics."

Formula for Loss Due to Sudden Expansion

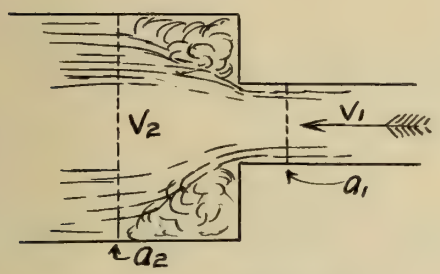


Fig. 12

$$\text{Head Lost} = h = \left(\frac{a_2}{a_1} - 1\right)\frac{V_2^2}{2g} \qquad (1)$$

$$h = \left(1 - \frac{a_1}{a_2}\right)\frac{V_1^2}{2g} \qquad (2)$$

— Formula for Loss Due to Sudden Contraction. —

The loss due to sudden contraction is really an expansion loss. The water leaving the larger section and entering the smaller suffers a contraction very much as in the case of the standard orifice, and in expanding to fill the smaller section losses by expansion.

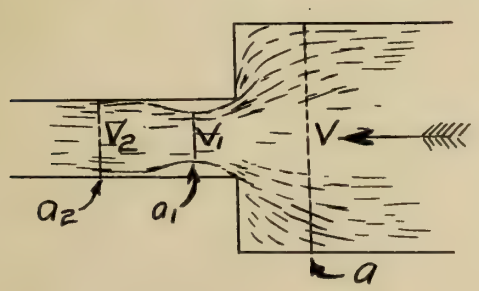


Fig. 13

$$h = \left(\frac{1}{C'} - 1\right)\frac{V_2^2}{2g} \qquad (3)$$

c' in this formula is the coefficient of contraction of the water after entering the smaller section.

The amount of contraction depends upon the relative sizes of a and a_2. If "a" were several times the size of a_2 the coefficient of contraction would be the same as for a standard orifice or about .62

Let d and d_2 be the diameters corresponding to a and a_2 and let $n = \frac{d_2}{d}$. Then the values of c' as determined experimentally are as follows:-

$n =$	0.0	0.4	0.6	0.7	0.8	0.9	0.95	1.0
$c' =$	.62	.64	.67	.69	.72	.79	.86	1.0

The contraction of the water after entering the smaller section will be referred to, as the "orifice contraction" and its coefficient (c') will be determined as above.

Two-Inch
Gate Valve Open

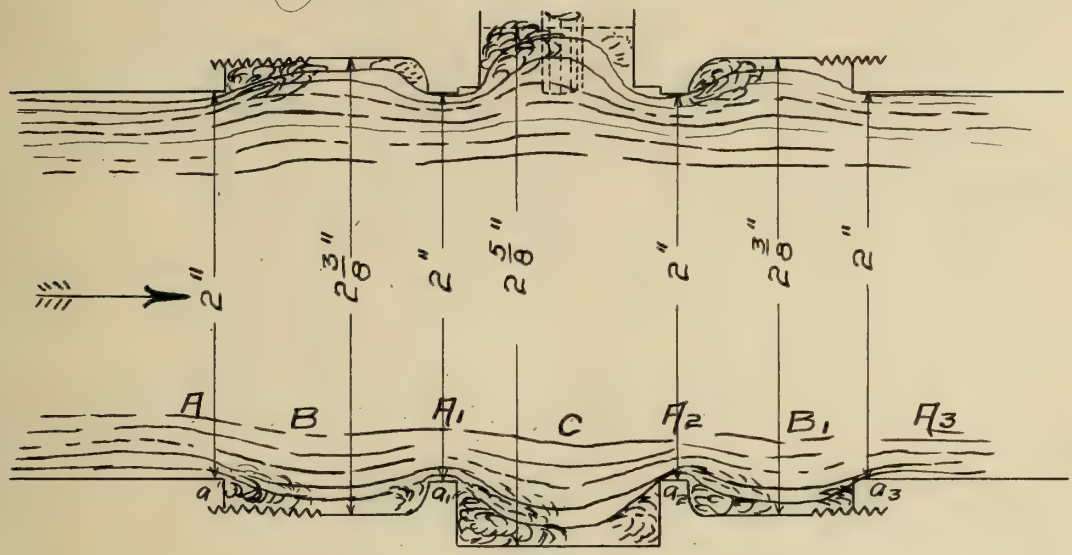


Fig. 14

Fig. 14 is a section of Crane and Co's 2-in. gate valve, drawn to scale (same as Fig 6), showing the expanding sections and formation of swirls

If the expanded sections B C and B1 are long enough for sudden expansion to take place and for the velocity to be reduced in proportion to the size of the section, the losses will then be figured by the formulae (1), (2) and (3)

Also there will be orifice contractions at the points a1 a2 and a3 and the real expansions will be from A to B, Contracted A1 to C Contracted A2 to B1 and Contracted A3 to A3

The total loss will then be figured as follows

Area A = A1 = A2 = A3 = 3.14 □" B = B1 = 4.42 □" C = 5.38 □"

Assume a velocity of 20 f/s through the pipe or velocity in $A, A_1, A_2, A_3, = 20$ f/sec

Expansion A to B 3.14 □" to 4.42 □"

From (1) $h = \left(\frac{4.42}{3.14} - 1\right)\frac{V_2^2}{64.3}$ $V_2 = \frac{3.14}{4.42} V = \frac{3.14 \times 20}{4.42} = 14.2$

$= .40 \frac{14.2^2}{64.3} = \underline{1.26}$

Expansion Contracted A_1 to C.

From (3) $h = \left(\frac{5.38}{3.14 \times .75} - 1\right)\frac{V_2^2}{64.3}$ $V_2 = \frac{3.14 \times 20}{5.38} = 11.7$

$= 1.28 \frac{11.7^2}{64.3} = \underline{2.73}$ $r = \frac{2}{2.38} = .85$ $\therefore c' = .75$

Expansion Contracted A_2 to B_1

From (3) $h = \left(\frac{4.42}{3.14 \times .67} - 1\right)\frac{V_2^2}{64.3}$ V_2 Same as A to B = 14.2

$= 1.09 \frac{14.2^2}{64.3} = \underline{3.40}$ $r = .6$ $\therefore c' = .67$

Expansion Contracted A_3 to A_3 $V_2 = V = 20$

From (3) $h = \left(\frac{1}{.75} - 1\right)\frac{V_2^2}{64.3}$ $r = .85$ $\therefore c' = .75$

$= .33 \frac{400}{64.3} = \underline{2.05}$

Then
1.26
2.73
3.40
2.05
9.44 = Total Head Lost.

But the head lost as determined experimentally is 2.20 ft (See Curve page 10)

Owing to the shortness of the expanded parts

B C & B_1 and to the formation of swirls and foam it does not seem probable that there would be any orifice contractions at the points a_1 a_2 and a_3, there being possibly some contraction at a_3.

Now figuring the loss without any orifice contractions we have:—

Expansion A to B.

Loss same as before = 1.26

Expansion A_1 to C

From (1) $h = \left(\frac{5.38}{3.14} - 1\right)\frac{11.7^2}{64.3} = 1.49$

Expansion A_2 to B_1

Loss same as before = 1.26

Then
1.26
1.49
1.26
4.01 Total Loss Considering no contractions

Which is still much larger than the actual loss of 2.20

The theoretical loss of 4.01 is based upon the assumption that the velocities in the expanded sections B C and B_1 are reduced in proportion to the section. It seems probable owing to the

shortness of the sections that the velocity would not be reduced proportionally. In this case there would not be as much impact loss due to change in velocity and the loss of 4.01 ft would reduce probably to somewhat near the actual loss of 2.20 ft.

Since the formulas for loss of head vary as the (velocity)^2 then the curve showing the relation between Velocity and Head Lost would be a parabola theoretically. Also since the experimental curve showing this relation is very nearly a parabola as is shown later, it is not necessary to compare the theoretical and actual head lost for more than one velocity.

Two-Inch
Gate Valve Half Open

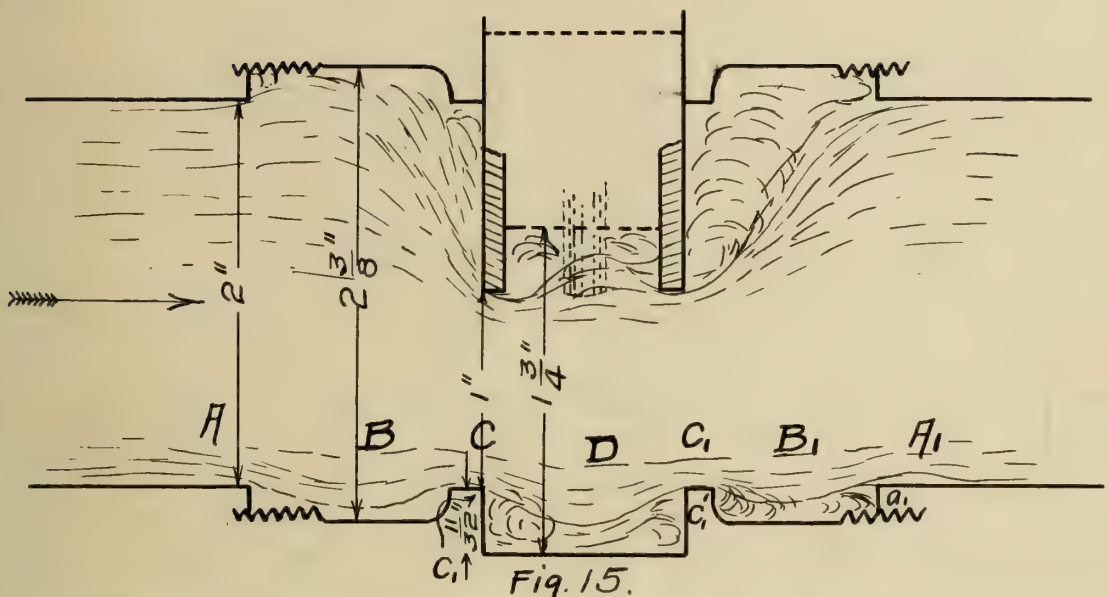


Fig. 15.

Fig 15 represents the action of the water in a 2-in. Crane gate valve. The fig. is drawn to scale and is the same as Fig. 6 The expanded sections are B, D and B_1

Section $A = A_1$ and is a 2-in circle. Section $B = B_1$ and is a $2\frac{3}{8}$-in circle.

Section $C = C_1$ and is the area enclosed by a 2" circle overlapped $\frac{1}{2}$ by a $2\frac{5}{8}$"-in circle.

Section D is the area enclosed by a $2\frac{5}{8}$"-in circle overlapped $\frac{1}{3}$ by a $2\frac{5}{8}$"-in circle.

Area Enclosed by Overlapping Circles in a Gate Valve.

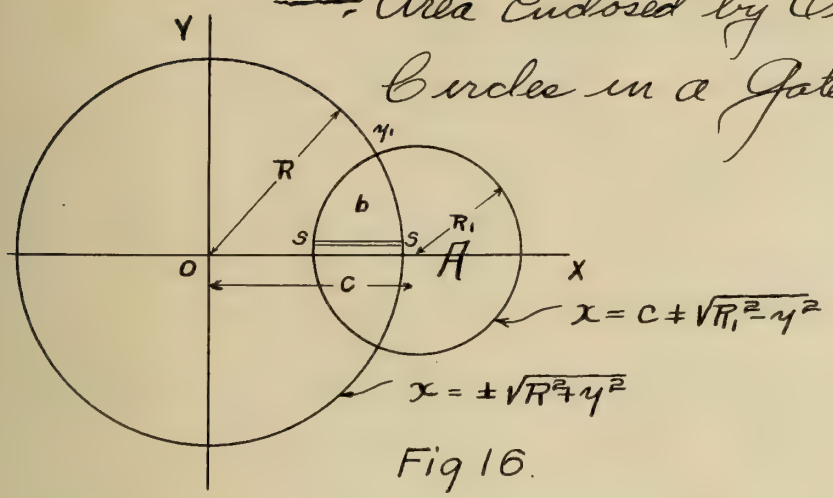


Fig 16.

The large circle R is the gate which closes over the small circle with a radius R_1 representing the valve seat. The area left open is A and is equal to $\pi R_1^2 - 2b$ Letting the circles be referred to the origin O in the figure and finding the area b by the calculus, we can then find the area A.

The equations of the circles are as given in the figure. Taking the differential strip S-S and integrating between the circles and y_1 as limits we have.—

$$b = \int_0^{y_1} \int_{c \pm \sqrt{R_1^2 + y^2}}^{\sqrt{R^2 - y^2}} dy\, dx.$$

$$b = \int_0^{y_1} \left(\sqrt{R^2 - y^2} - \left[c - \sqrt{R_1^2 - y^2} \right) \right] dy$$

$$b = \left[\frac{y}{2} \sqrt{R^2 - y^2} + \frac{R^2}{2} \sin^{-1} \frac{y}{R} - cy + \frac{y}{2} \sqrt{R_1^2 - y^2} + \frac{R_1^2}{2} \sin^{-1} \frac{y}{R_1} \right]_0^{y_1}$$

$$b = \frac{y_1}{2}\sqrt{R^2-y_1^2} + \frac{R^2}{2}\sin^{-1}\frac{y_1}{R} - cy_1 + \frac{y_1}{2}\sqrt{R_1^2+y_1^2} + \frac{R_1^2}{2}\sin^{-1}\frac{y_1}{R_1}$$

But in the case where the valve is half closed $c = R$ Then the equations of the circles would be $x = \sqrt{R^2-y^2}$ and $x = R \pm \sqrt{R_1^2-y^2}$

y_1 is a point on both circles and can be found by solving the equations of the circles simultaneously If valve is half closed

$$y_1 = \sqrt{R_1^2 - \frac{R_1^4}{4R^2}}$$

Also since Area $A = \pi R_1^2 - 2b$, we have for the valve half closed,

$$A = \pi R_1^2 - 2\left(\frac{y_1}{2}\sqrt{R^2-y_1^2} + \frac{R^2}{2}\sin^{-1}\frac{y_1}{R} - Ry_1 + \frac{y_1}{2}\sqrt{R_1^2+y_1^2} + \frac{R_1^2}{2}\sin^{-1}\frac{y_1}{R_1}\right)$$

$$= \pi R_1^2 - y_1\left(\sqrt{R^2-y_1^2} + \sqrt{R_1^2-y_1^2}\right) - R^2\sin^{-1}\frac{y_1}{R} - R_1^2\sin^{-1}\frac{y_1}{R_1} + 2Ry_1$$

In the two inch valve half closed $R = 1.31''$

$R_1 = 1.00''$ $y_1 = .925''$

$$\therefore A = 3.1416 - .925\left(\sqrt{1.725-.855} + \sqrt{1-.855}\right) - 1.725\sin^{-1}.778 - 1.00\sin^{-1}.925 + 1.21$$

$$A = 3.1416 - 1.362 = 1.78\ \square''$$

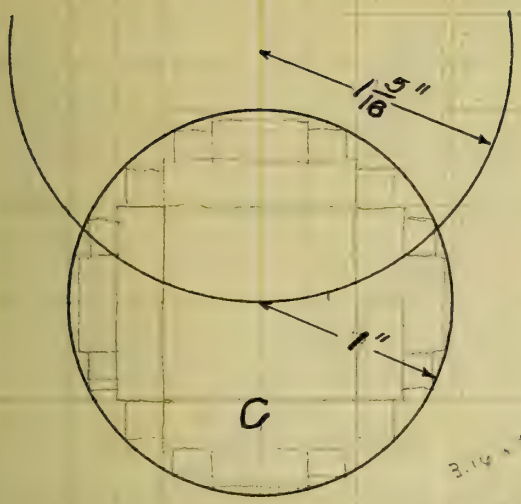


Fig. 17

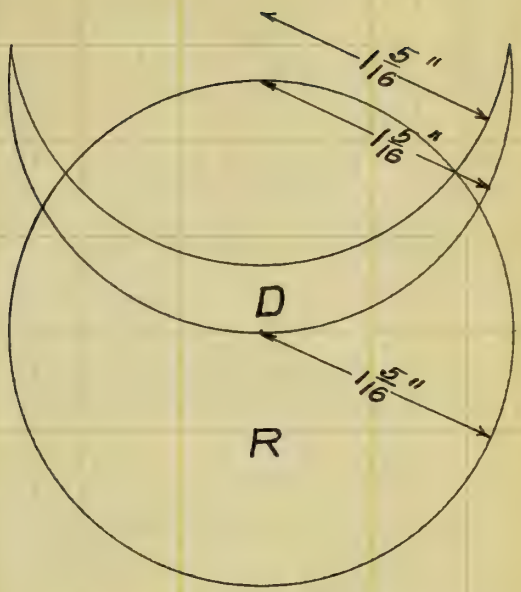


Fig. 18

By drawing the circles R and R_1 to scale and counting the small squares in order to obtain the area sought (4 of the smallest squares (□) equaling .01 □") we get for C Fig 17 1.80 □"
R Fig 18 3.30 □"
D Fig 18 4.01 □"
This graphic method of obtaining the areas will hereafter be used for irregular sections since it agrees closely with the calculus method and is quicker

The area A by the Calculus Method = 1.78 □"
Graphics Method = 1.80 □"

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Losses In a Two Inch Gate Valve Half Closed.

The area of Section $A = A_1 = 3.14$ □" $B = B_1 = 4.42$ □"

$C = C_1 = 1.78$ □" (by calculus) $D = 4.01$ □" (Graphic method)

From Fig. 18.

Assume a velocity of 20 f/s through pipe (Sect. A & A_1)

Expansion A. to B.

Loss same as when valve is open = 1.26 ft.

Expansion-C to D

From (1) $h = \left(\frac{4.01}{1.78} - 1\right)\frac{V_2^2}{2g}$ $\qquad V_2 = \frac{3.14 \times 20}{4.01} = 15.7$

$= 1.25\frac{15.7^2}{64.3} = \underline{9.60}$

Expansion-C_1 to B_1

From (1) $h = \left(\frac{4.42}{1.78} - 1\right)\frac{400}{64.3} = \underline{9.20}$

Then
$$\begin{array}{r} 1.26 \\ 9.60 \\ 9.20 \\ \hline 20.06 \end{array} = \text{Total head lost theoretically.}$$

The loss as determined experimentally = 18.5 (See curve page 10 vel = 20 f/sec) Since the agreement is fairly close it is not necessary to make farther investigations with this valve.

One-Inch
Gate Valve Open

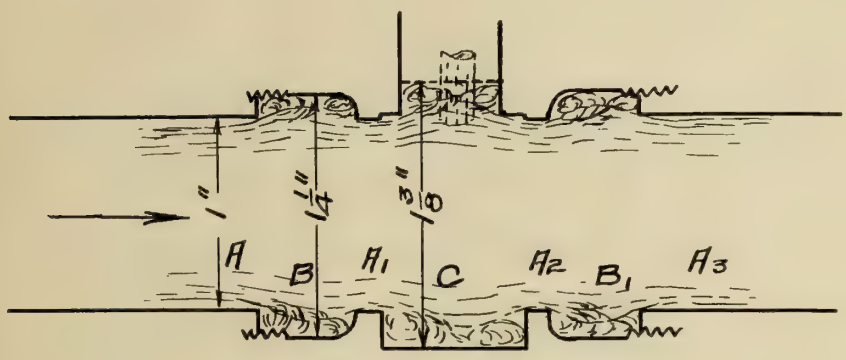

Fig. 19

Proceed as before assuming that there is little or no orifice contraction.

Area $A = A_1 = A_2 = A_3 = .790$ □" Area $B = B_1 = 1.230$ □"

Area $C = 1.500$ □" Assume a vel. of 20 ft/s. through A.

Expansion A to B.

From (1) $h = \left(\frac{1.23}{.79} - 1\right)\frac{V_2^2}{64.3}$ $V_2 = \frac{.79 \times 20}{1.23} = 12.8$

$= .56\frac{\overline{12.8}^2}{64.3} = \underline{1.43}$

Expansion A_1 to C

From (1) $h = \left(\frac{1.50}{.79} - 1\right)\frac{V_2^2}{64.3}$ $V_2 = \frac{.79 \times 20}{1.50} = 10.5$

$= 1.0\frac{\overline{10.5}^2}{64.3} = \underline{1.70}$

Expansion A_2 to B_1

Same as in expansion from A to B = 1.43

Then
$$\begin{array}{r} 1.43 \\ 1.70 \\ 1.43 \\ \hline 4.56 \text{ ft.} \end{array}$$ Total theoretical head lost.

The actual head lost for same conditions is 4.80 ft. See curve page.

The head lost for other velocities would agree equally well since as before stated the theoretical curve is practically a parabola and the curves determined experimentally are very nearly parabolas as will be shown later.

One-Inch

= Gate Valve Half Open =

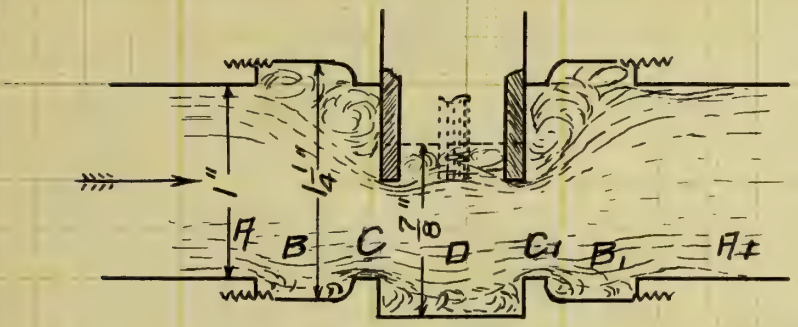

Fig. 20

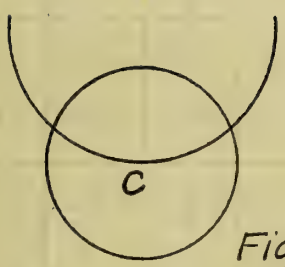

Fig. 21

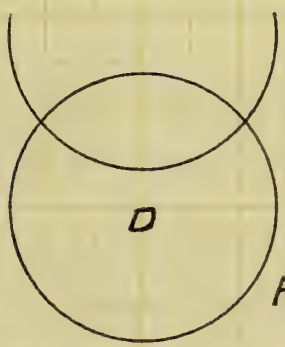

Fig. 22

Area $C = C_1 = \frac{.79}{2} + .5 = .44$ □"

Area $D = \frac{1.48}{2} + .40 = 1.14$ □"

Area $A = A_1 = .79$ □"

Area $B = B_1 = 1.22$ □"

Assuming a velocity of 10 f/sec and proceeding as before

Expansion A to B

From (1) $h = \left(\frac{1.22}{.79} - 1\right)\frac{V_2^2}{2g}$ $V_2 = \frac{.79}{1.22} \times 10 = 6.5$

$= .55\,\frac{6.5^2}{64.3} = .36$

Expansion C to D

From (1) $h = \left(\frac{1.14}{.44} - 1\right)\frac{V_2^2}{64.3}$ $V_2 = \frac{.79}{1.14} \times 10 = 7.0$

$h = 1.60\,\frac{49}{64.3} = 1.22$

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Expansion C_1 to B_1

From (1) $h = \left(\frac{1.22}{.44} - 1\right)\frac{6.5^2}{64.3}$ V_2 = Same as A to B = 6.5

$= 1.78\frac{6.5^2}{64.3} = 1.17$

Then .36
1.22
1.17
2.75 Total Head Lost.

The actual loss in a one inch gate valve $\frac{1}{2}$ open is 11.0 ft. for a velocity of 10 f/s. There is no agreement between the two results.

Since a one inch valve is small and the enlarged sections B, D, and B_1 are longer in proportion to the diameter than in a two-inch valve, it is probable that the full effect of sudden expansion of section, and the orifice contraction, (this last being neglected in the above calculations) due to sudden contraction of section, would both be found to take place.

Therefore revising the calculations and taking into consideration the probable amount of contraction the results are as follows. Vel. in A being 10 f/s.

Expansion A to B

This loss is the same as before = .36

Expansion Contracted C. to D.

From (3) $h = \left(\frac{1.14}{.44 \times .70} - 1\right) \frac{49}{64.3}$

$= 2.70 \frac{49}{64.3}$

$= \underline{2.05}$ ft.

V_2 Same as before = 7.0

C' will have to be assumed and will be about .70

Expansion Contracted C_1 to B_1

From (3) $h = \left(\frac{1.22}{.94 \times .70} - 1\right) \frac{\overline{6.5}^2}{64.3}$

V_2 Same as before = 6.5

C' assumed as before = .70

$= 2.96 \frac{\overline{6.5}^2}{64.3} = \underline{1.94}$

Expansion Contracted A_1 to A_1

From (3) $h = \left(\frac{1}{.72} - 1\right) \frac{100}{64.3}$

$r = \frac{1.6}{1.25} = .60$

$\therefore c = .72$

$= .39 \frac{100}{64.3} = \underline{0.60}$

Then

.36
2.05
1.94
.60
4.95 ft Total head lost, which is about one half of the actual loss = 11.0 ft. The rest of the actual loss will have to be accounted for by friction on the rough surface of the valve and by impact against the half closed gate. Neither of these last losses can be arrived at theoretically.

INVESTIGATION
of
LOSS OF HEAD
in.
GLOBE VALVES.

2-in. Globe Open, $\frac{1}{2}$ Open.

1-in. Globe Open $\frac{1}{2}$ Open.

Head Lost in Globe Valves.

Since the calculations for loss of head in gate valves but roughly approximated the actual it would be useless in the case of globe valves to try to calculate the same. The loss by expansion of sections is probably but a small part of the loss. The various turns and deflections can not be told and, therefore the impact against the surfaces causing the same could not be calculated.

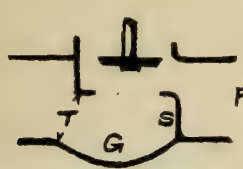


Fig. 23
Globe Valve

It seemed to the writer that the section G Fig 23 was much larger than the throat section T and that there would be loss by expansion from throat to globe. Furthermore there would be loss of head by the water impinging on the vertical surface S.

The experiment of filling in the globe G with plaster of paris, to reduce this expanded section and form a curved surface to deflect the water up through the valve was tried.

This filling in, did not seem to decrease nor

to increase the loss through the valve. (see curves etc page)

The curves being the same as before, practically. The curves for the valve one half closed being identical in both cases.

The valves used on feed pipes to boilers sometimes fill in with lime in about this manner and according to the experiment considerable deposit could form and the flow through the valve would not be affected.

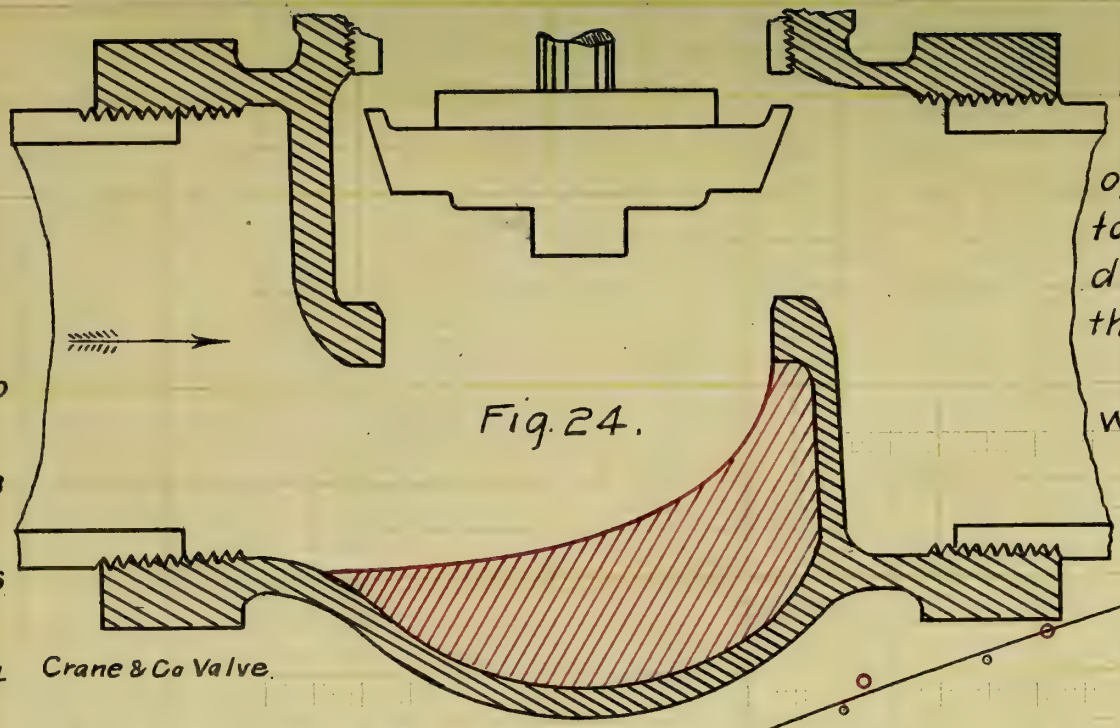


Fig. 24.

Crane & Co Valve.

Note:—
The red hatched section was plaster of paris filled in the globe of the valve to prevent loss by expansion and to direct the flow through the valve and thus obtain less loss of head
This filling in, had no effect either way as shown by the curves.

Open

½ Open

44

Velocity in ft/sec.

○ Natural Section.
○ Filled In Section.

Curves Showing Relation between Velocity and Head Lost in 2-in. Globe Valve

The Results obtained by filling in Section as Shown are practically the same as with natural section.

Head Lost in Feet

2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

2 4 6 8 10 12 14 16 18 20

INVESTIGATION

of

LOSS OF HEAD

in

ANGLE VALVES

2-in Angle Open $\frac{1}{2}$ Open $\frac{2}{3}$ Open.

1-in Angle Open $\frac{1}{2}$ Open $\frac{2}{3}$ Open.

— Angle Valves —

Angle Valve Open

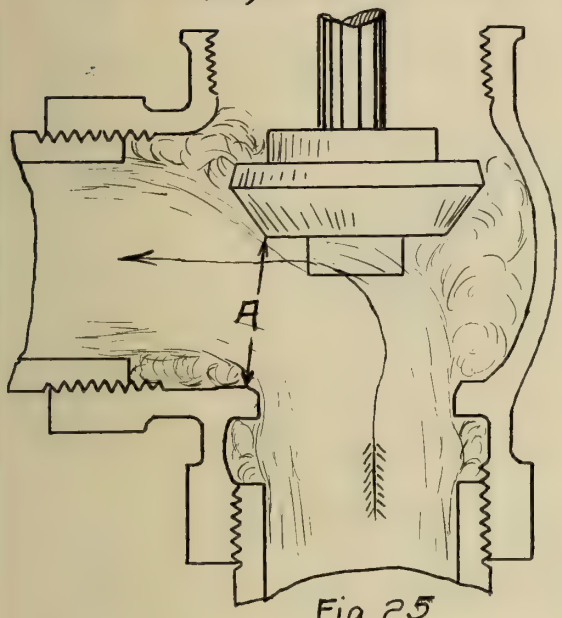


Fig. 25

A for 2" Valve = 1.25"
A for 1" Valve = .75"

Angle Valve $\frac{2}{3}$ Open.

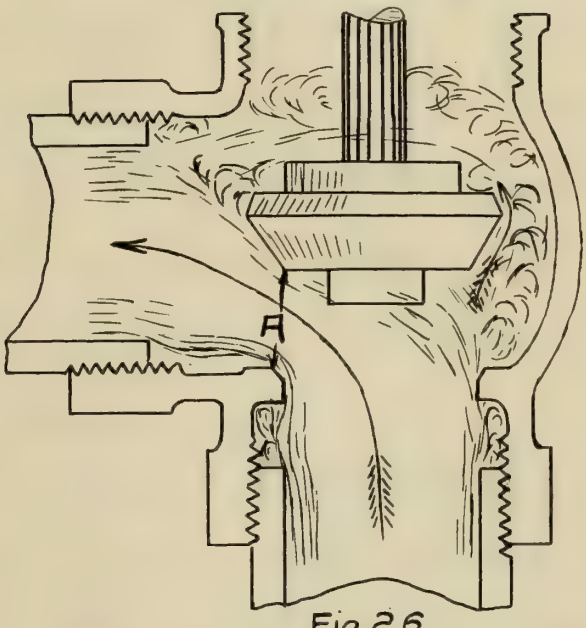


Fig 26

A for 2" valve = .85"
A for 1" Valve = .50"

Angle Valve $\frac{1}{2}$ Open

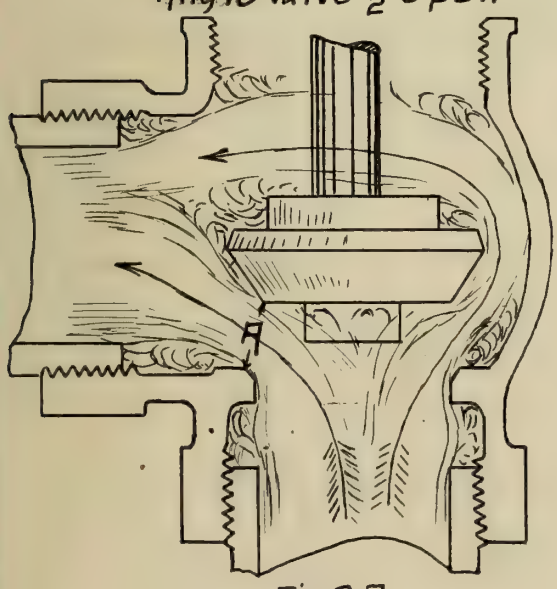


Fig 27

A for 2" Valve = .63"
A for 1" Valve = .38"

— Loss of Head in Angle Valves. —

The angle valves tested both gave peculiar results in having a maximum discharge when about two thirds open. The discharge for the valve open was practically equal to the discharge for the valve half open.

(See curves pages 14, 15)

A possible explanation of these results can be made by the use of Figures 25, 26 & 27. page 46.

A in these figures is the distance from the edge of the valve disk to the edge of the valve seat. When the valve is open (Fig. 25) there is no opportunity for the water to pass up around the disk, but must pass through under the same Hence, the section through which the water must pass is semi-cylindrical having a depth A and a length equal to one half the circumference of the valve seat.

Equal in the case of the two inch valve (see page 21) to $A \times \frac{2\pi r}{2} = 1.25 \times 3.14 \times 1 = 3.940''$

When the valve is half open there is an opportunity for the water to pass through all around the disk and into the valve. The section

in this case would be a cylinder with a depth A (Fig 27) and a circumference equal to that of the valve seat, or for 2-in valve equal to $A \times 2\pi r = .63 \times 2 \times 3.14 \times 1 = 3.94$ □" This section is the same as the section figured for the valve when open, therefore one would expect the discharge for the valve half closed to be the same as when open.

When the valve is half closed the area between the seat and the disk is 3.94 □" for a 2-in valve, and the area of the seat (a 2" circle) is 3.14 □" As the valve closes this area of 3.94 is reduced to zero and at the same time the loss of head constantly increases. This is as one would expect, but in opening the valve the head lost for any discharge is a minimum at the $\frac{2}{3}$ point, the head lost increasing as the valve is opened from $\frac{2}{3}$ open to fully open.

How, just why there is a minimum head lost when the valve is between $\frac{1}{2}$ open and open is rather hard to explain.

The section area through which the water must pass is 3.94 □" for the valve both open

and $\frac{1}{2}$ open and the area of a 2 in pipe is 3.14 □" Hence there is an expansion loss from area 3.14 □" to 3.94 □"

If most of the water still be considered as passing under the disk as shown in Fig. 26. the section A is less than 3.94 □" and equal approximately to 3.14 □" Hence there would be less loss of head by expansion and the minimum loss of head when the valve is $\frac{2}{3}$ open would be accounted for.

The conditions for a one inch angle valve are about the same as for the 2" valve.

Now A for 2" ∠ valve open = 1.25"

A for 1" ∠ valve open = .75"

Both distances A being about $\frac{1}{4}$ larger than $\frac{1}{2}$ size of the valve. Hence an approximate rule for designing the lift for an angle valve would be:-

The distance which the valve disk should lift from the valve seat in an angle valve should not be more than one half the size of the valve in inches.

FORMULAS EXPRESSING THE LOSS OF HEAD IN TERMS OF THE VELOCITY

— Formulas Giving Loss of Head in Terms of the Velocity. —

It was shown in the previous discussions that the theoretical formulas giving loss of head contained the term $\frac{V^2}{2g}$ Hence one would expect the curves showing the relation between velocity and head lost to be parabolas of the general form $V^2 = mH$ in which V = velocity in the pipe and H = head lost. This is shown to be true by a comparison between the actual curves and the theoretical curves derived from them. They agree very closely as shown by the curves page 54.

A point on the actual curve which is well defined by experimental results is taken as a point on the parabola and the equation of the parabola determined by finding the value of the constant m. The average of several m's for one curve would give a better result but the close agreement of the curves does not require this.

$$V^2 = mH$$

$$\therefore \quad H = \frac{V^2}{m}$$

FOR 2-IN. GATE VALVE OPEN

From curve page When V = 10 H = .5 m = 200

V = 20 H = 2.2 m = 182

V = 25 H = 3.4 m = 184

3) 566

Av. m = 188

$\therefore H = \frac{V^2}{188}$ OR $= 0.34 \frac{V^2}{2g}$

$\frac{1}{2}$ OPEN $H = \frac{V^2}{22}$ OR $= 2.92 \frac{V^2}{2g}$

FOR 1-IN. GATE VALVE

OPEN $H = \frac{V^2}{85}$ OR $= 0.76 \frac{V^2}{2g}$

$\frac{1}{2}$ OPEN $H = \frac{V^2}{9}$ OR $= 7.15 \frac{V^2}{2g}$

FOR 2-IN. GLOBE VALVE

OPEN $H = \frac{V^2}{11}$ OR $= 5.85 \frac{V^2}{2g}$

$\frac{1}{2}$ OPEN $H = \frac{V^2}{5.8}$ OR $= 11.10 \frac{V^2}{2g}$

FOR 1-IN. GLOBE VALVE

OPEN $H = \frac{V^2}{9}$ OR $= 7.15 \frac{V^2}{2g}$

$\frac{1}{2}$ OPEN $H = \frac{V^2}{7}$ OR $= 9.20 \frac{V^2}{2g}$

FOR 2-IN. ANGLE VALVE

Min. head lost $\frac{2}{3}$ open $H = \frac{V^2}{48}$ OR $= 1.34 \frac{V^2}{2g}$

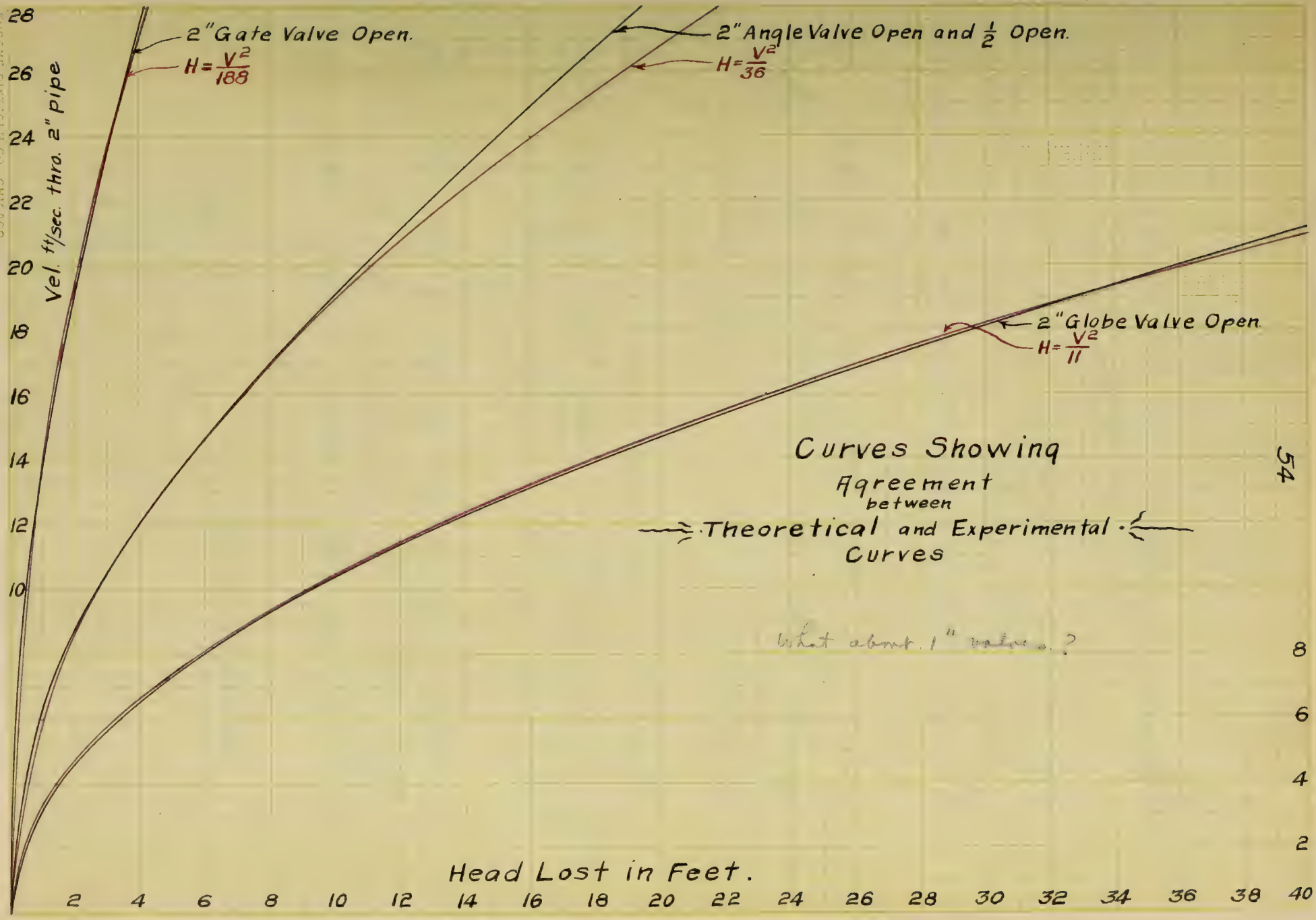
$\frac{1}{2}$ OPEN and OPEN $H = \frac{V^2}{36}$ OR $= 1.78 \frac{V^2}{2g}$

→ FOR 1-IN. ANGLE VALVE ←

Min. head lost $\frac{2}{3}$ open $H = \frac{V^2}{24}$ OR $= 2.68 \frac{V^2}{2g}$

$\frac{1}{2}$ OPEN and OPEN $H = \frac{V^2}{21}$ OR $= 3.06 \frac{V^2}{2g}$

From the above formulas it is seen that the head lost in the one inch valves is roughly twice the head lost in the corresponding two inch valves.


2" Gate Valve Open.
$H = \frac{V^2}{188}$
2" Angle Valve Open and $\frac{1}{2}$ Open.
$H = \frac{V^2}{36}$
2" Globe Valve Open
$H = \frac{V^2}{11}$
Vel. ft/sec. thro. 2" pipe
28
26
24
22
20
18
16
14
12
10
8
6
4
2
Head Lost in Feet.
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Curves Showing
Agreement
between
Theoretical and Experimental
Curves
What about 1" valve ?
54
SUGGS CURTAIN CO., CHICAGO.

Conclusion

Summing up the matter here presented the main facts established are:—

I The curves showing the relation between velocity and head lost are parabolas of the form $H = \frac{V^2}{m}$ as determined pages 50 to 54)

II The bottom of a globe valve may become half filled with sediment, and the flow through the valve will be the same as before. (see pages 42 to 45)

III An angle valve loses as much head when open as when half closed and the minimum loss of head obtains when the valve is about $\frac{2}{3}$ open

IV The lift of the disk of an angle valve in inches should not be more than one half the size of the valve in inches (see pages 49 to 50)

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